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MEMORANDUM

WIND-TUNNEL INVESTIGATION AT MACH NUMBERS FROM 0.40 TO 1.14 OF THE STATIC AERODYNAMIC CHARACTERISTICS OF A NONLIFTING VEHICLE SUITABLE FOR REENTRY

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

An investigation was conducted in the Langley 8-foot transonic pressure tunnel to investigate the static pitching-moment, normal-force, and axial-force characteristics on a model of a nonlifting vehicle suitable for reentry. The vehicle was designed to use a heat sink and blunt shape to alleviate the effects of the heating encountered during reentry of the earth's atmosphere. The effects of modifying the intersection of the face of the model with the afterbody from a sharp corner to a rounded edge were also investigated.

Tests were conducted at Mach numbers from 0.40 to 1.14 and at angles of attack from approximately -3° to 20°. The Reynolds number varied from about 2.0×10^{6} to 3.6×10^{6}.

The results show that the model had a low positive static-stability level, low normal-force coefficients, and large axial-force coefficients. The model trimmed, for the angle-of-attack range investigated, at angles of attack near zero. The effects on the stability as a result of rounding the corner were negligible.

INTRODUCTION

The concept of using a blunt shape and a heat sink to alleviate the effects of the heating encountered during reentry of the earth's atmosphere is now well known (ref. 1). With the use of this concept, a nonlifting vehicle suitable for reentry is being designed by the National Aeronautics and Space Administration. In order for this vehicle to reenter the earth's atmosphere and impact with the earth in a proper attitude, it is necessary for the configuration to trim and have positive static stability only with the heat sink facing the relative wind.

The NASA has, therefore, initiated a wind-tunnel research program to investigate the static aerodynamic characteristics of models of blunt nonlifting vehicles suitable for reentry. This program is being carried out in several facilities over a wide range of Mach numbers. Static aerodynamic characteristics obtained at supersonic speeds on two of these models are presented in reference 2. The present investigation, which was performed in the Langley 8-foot transonic pressure tunnel, provides information at subsonic and transonic speeds on one of the models of reference 2. This investigation was conducted over an angle-of-attack range from about -3° to 20° at Mach numbers from 0.40 to 1.14. The Reynolds number, based on the maximum body diameter, varied from about 2.0×10^{6} to 3.6×10^{6}.

SYMBOLS

The data presented herein are referred to the body system of axes with the origin located at the center-of-gravity position. The positive directions of forces, moments, and displacements are shown in figure 1. The coefficients and symbols are defined as follows:

C_m pitching-moment coefficient, $\frac{\text{Pitching moment}}{qAd}$

C_{m_α} slope of pitching-moment coefficient per degree at $\alpha \approx 0^{\circ}$, $\frac{\partial C_m}{\partial \alpha}$

C_A axial-force coefficient, $\frac{\text{Axial force}}{qA} - C_{A,b}$

$C_{A_{\alpha \approx 0}}$ axial-force coefficient at $\alpha \approx 0^{\circ}$

$C_{A,b}$ base axial-force coefficient, $-\frac{(\text{Base pressure}) \times A_b}{qA}$

C_N normal-force coefficient, $\frac{\text{Normal force}}{qA}$

C_{N_α} slope of normal-force coefficient per degree at $\alpha \approx 0^{\circ}$, $\frac{\partial C_N}{\partial \alpha}$

d maximum body diameter, in.

M	free-stream Mach number
q	free-stream dynamic pressure, lb/sq ft
R	Reynolds number based on maximum body diameter and free-stream conditions
A	maximum cross-sectional area, sq ft
A_b	base area, sq ft
α	angle of attack of model center line, deg

MODEL, TESTS, AND ACCURACY

The model, which was a body of revolution, was made of aluminum alloy and consisted of an afterbody with interchangeable face plates, one having a sharp corner and the other a rounded edge. Details of this model, including the modified intersection of the blunt face and afterbody, are shown in figure 2, and photographs are presented in figure 3.

The model was mounted on a three-component strain-gage balance and was sting supported in the tunnel as shown in figure 3. The construction of the sting-support system is such that the model remained near the tunnel center line throughout the angle-of-attack range.

The investigation was conducted in the Langley 8-foot transonic pressure tunnel at Mach numbers from 0.40 to 1.14. The tests were performed at a stagnation pressure of 1 atmosphere and at a dewpoint temperature such that the air flow was free of condensation shocks. The variation of Reynolds number, based on maximum body diameter, with Mach number is shown in figure 4. The model angle of attack, which was varied from -3° to 20°, was determined by means of a calibrated fixed-pendulum strain-gage unit mounted in the forward portion of the model. Corrections have been applied for a tunnel flow angularity of approximately 0.2°. All data presented from this investigation are essentially free of wall-reflected disturbances.

Normal force, axial force, and pitching moment were determined by means of the internal strain-gage balance with the pitching moments taken about the center of gravity. The axial-force results have been adjusted to a condition of free-stream static pressure at the model base. Based upon balance accuracy and repeatability of data, it is estimated that the coefficients of normal force, axial force, and pitching moment are accurate within ±0.020, ±0.020, and ±0.005, respectively, at a Mach number of 0.40, but this accuracy improves at the higher Mach numbers because of an increase in dynamic pressure. The maximum variation of the actual test Mach numbers from the presented nominal values is less than ±0.005. The accuracy of the angle of attack is estimated to be within $\pm 0.10^{\circ}$.

DISCUSSION

Static Stability and Trim Characteristics

It may be seen from figures 5(a) and 6 that the model has a low positive static-stability level at the lower angles of attack throughout the Mach number range of this investigation and that near a Mach number of 0.90 the model is nearly neutrally stable. The stability level, however, increases at the higher angles of attack for all Mach numbers.

The data of figure 5(a) also show that the model trims at an angle of attack near 0° and that no other trim points exist at the higher angles of attack investigated. These results, for the angle-of-attack range investigated, show that the model trims and has positive static stability when the heat-sink portion is in a forward position. No dynamic-stability requirements, however, have been considered. The effects due to rounding the intersection of the face and afterbody are negligible on the static stability characteristics.

Normal- and Axial-Force Characteristics

As may be expected because of the nonlifting shape of the model, the normal-force coefficients shown in figure 5(b) are small throughout the angle-of-attack and Mach number ranges of this investigation. The values of C_{N_α}, determined at $\alpha \approx 0^{\circ}$, are negative throughout the Mach number range (fig. 6). The data of figure 5(c) show that, for a given Mach number, the axial-force coefficients are large and are essentially constant with variation of angle of attack. The base axial-force coefficients used to adjust the axial-force coefficients are shown in figure 5(d). The variation of $C_{A_{\alpha\approx0}}$ with Mach number shown in figure 6 follows the usual trend for the Mach number range of this investigation, that is, increasing values of $C_{A_{\alpha\approx0}}$ with Mach number with a maximum value occurring near a Mach number of about 1.05. The effects due to rounding the intersection of the model face and afterbody are negligible on the normal-force coefficients but tend to reduce the axial-force coefficients slightly.

CONCLUDING REMARKS

An investigation has been conducted in the Langley 8-foot transonic pressure tunnel to determine the static pitching-moment, normal-force, and axial-force characteristics of a model of a nonlifting vehicle suitable for reentry. This vehicle was designed to utilize a heat sink and blunt shape to alleviate the effects of the heating encountered during reentry of the earth's atmosphere. In addition, tests were made to investigate the effects of modifying the intersection of the face of the model with the afterbody from a sharp corner to a rounded edge. The tests were conducted at Mach numbers from 0.4 to 1.14 through an angle-of-attack range from approximately -3° to 20° and at Reynolds numbers from about 2.0×10^{6} to 3.6×10^{6}.

The model had a low positive static-stability level throughout the Mach number range investigated, and trim occurred at angles of attack near 0°. The effects on the stability due to modifying the model by changing the intersection of the face with the afterbody from a sharp corner to a rounded edge were negligible. The axial-force coefficient, however, was reduced slightly because of rounding the corner.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., January 20, 1959.

REFERENCES

1. Allen, H. Julian, and Eggers, A. J., Jr.: A Study of the Motion and Aerodynamic Heating of Missiles Entering the Earth's Atmosphere at High Supersonic Speeds. NACA TN 4047, 1957. (Supersedes NACA RM A53D28.)

2. Turner, Kenneth L., and Shaw, David S.: Wind-Tunnel Investigation at Mach Numbers From 1.60 to 4.50 of the Static-Stability Characteristics of Two Nonlifting Vehicles Suitable for Reentry. NASA MEMO 3-2-59L, 1959.

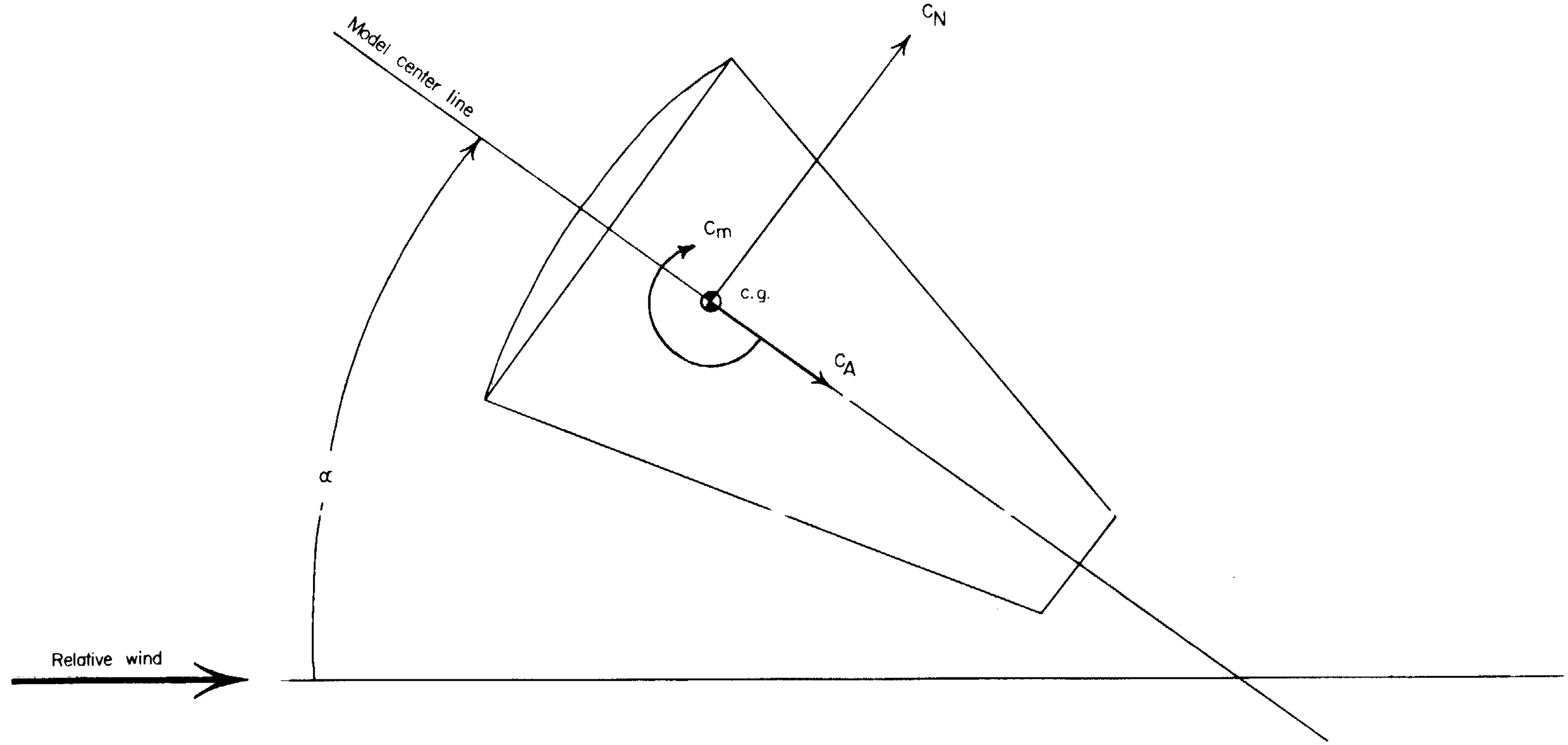


Figure 1.- Body axis system. Arrows indicate positive directions.

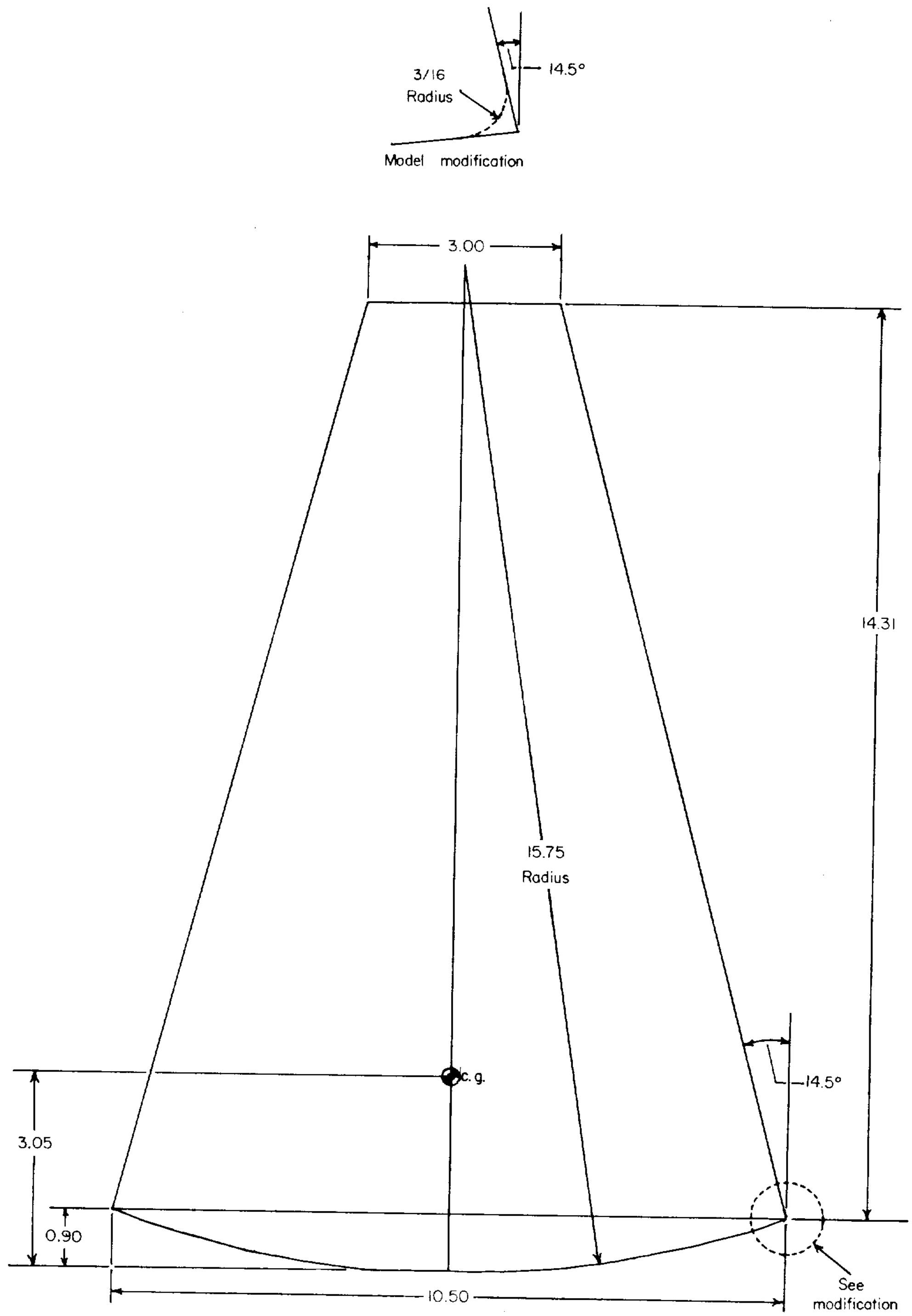
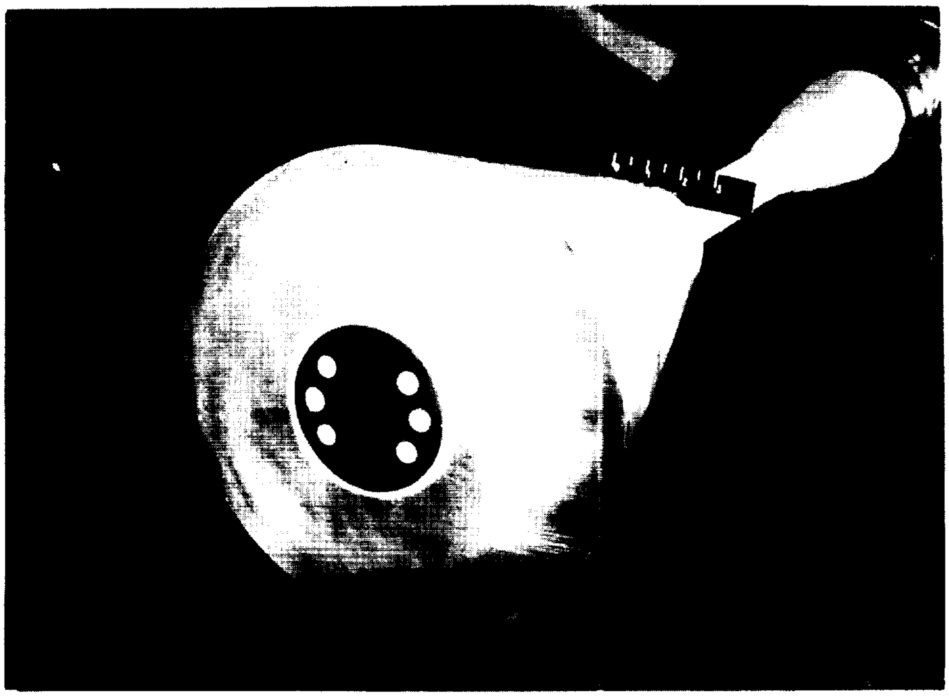
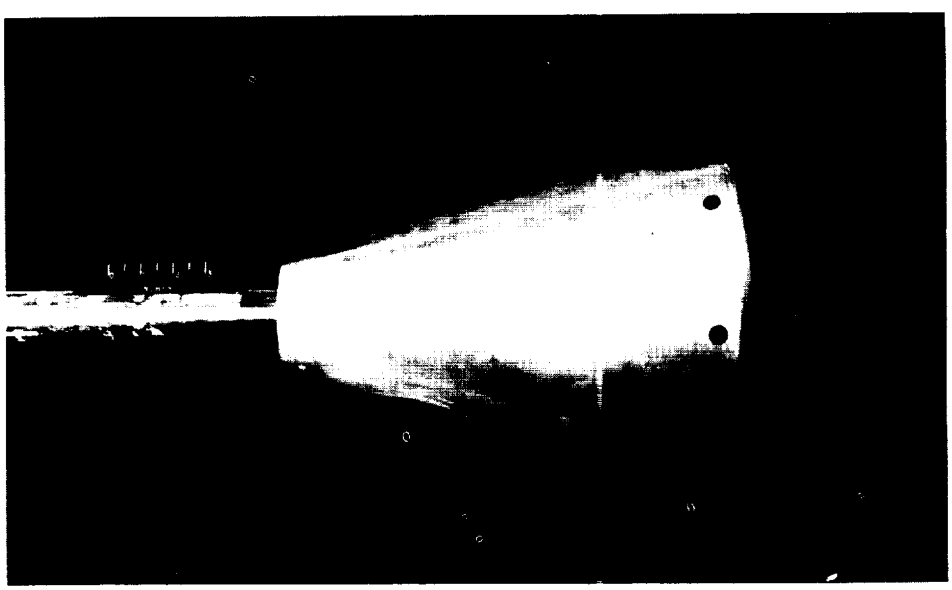


Figure 2.- Details of model. All dimensions are in inches unless otherwise noted.



(a) Sharp corner. L-58-3549



(b) Rounded edge. L-58-3655

Figure 3.- Photographs of model.

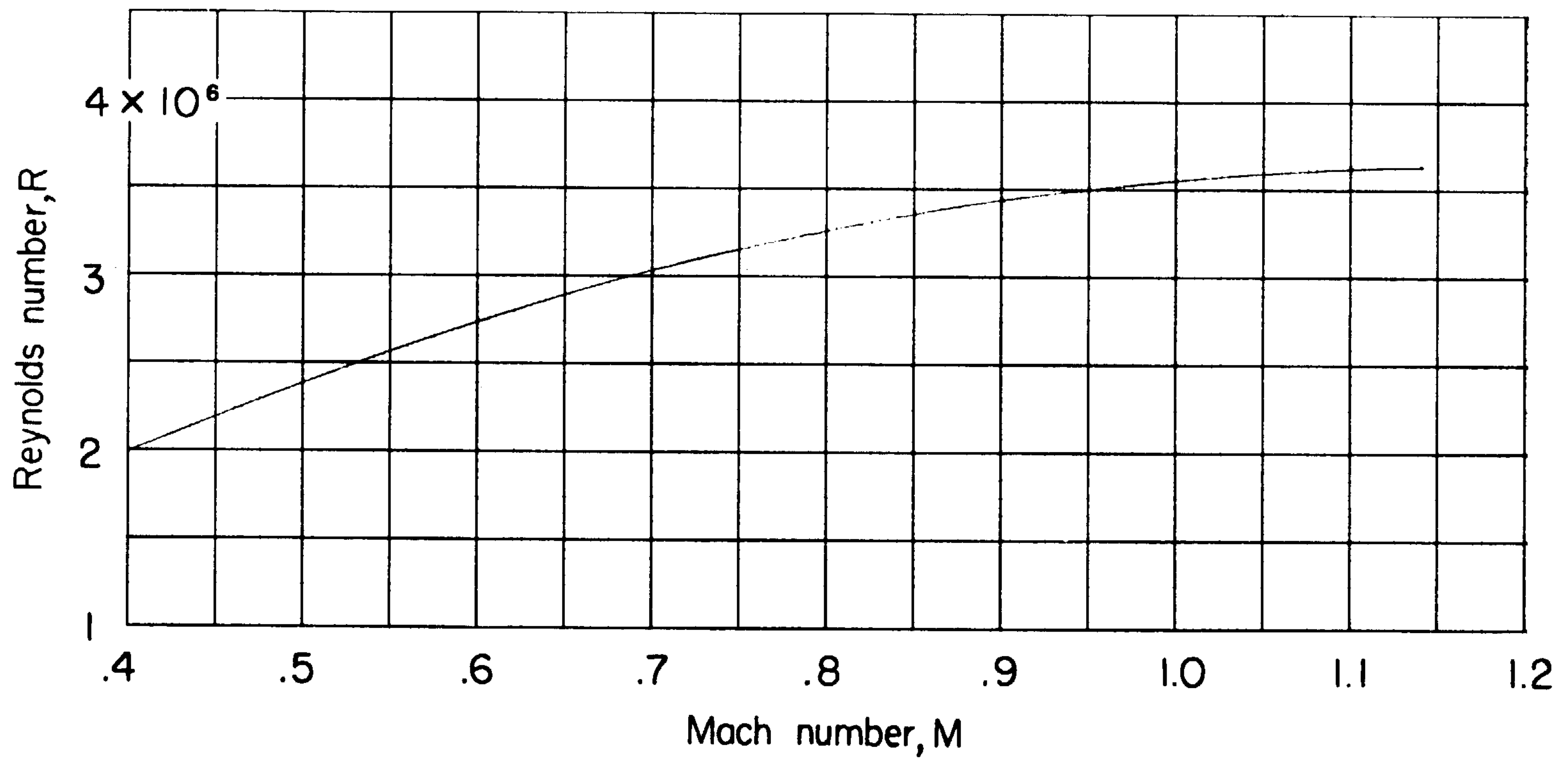


Figure 4.- Variation of test Reynolds number, based on maximum body diameter, with Mach number.

Figure 5.- Continued.

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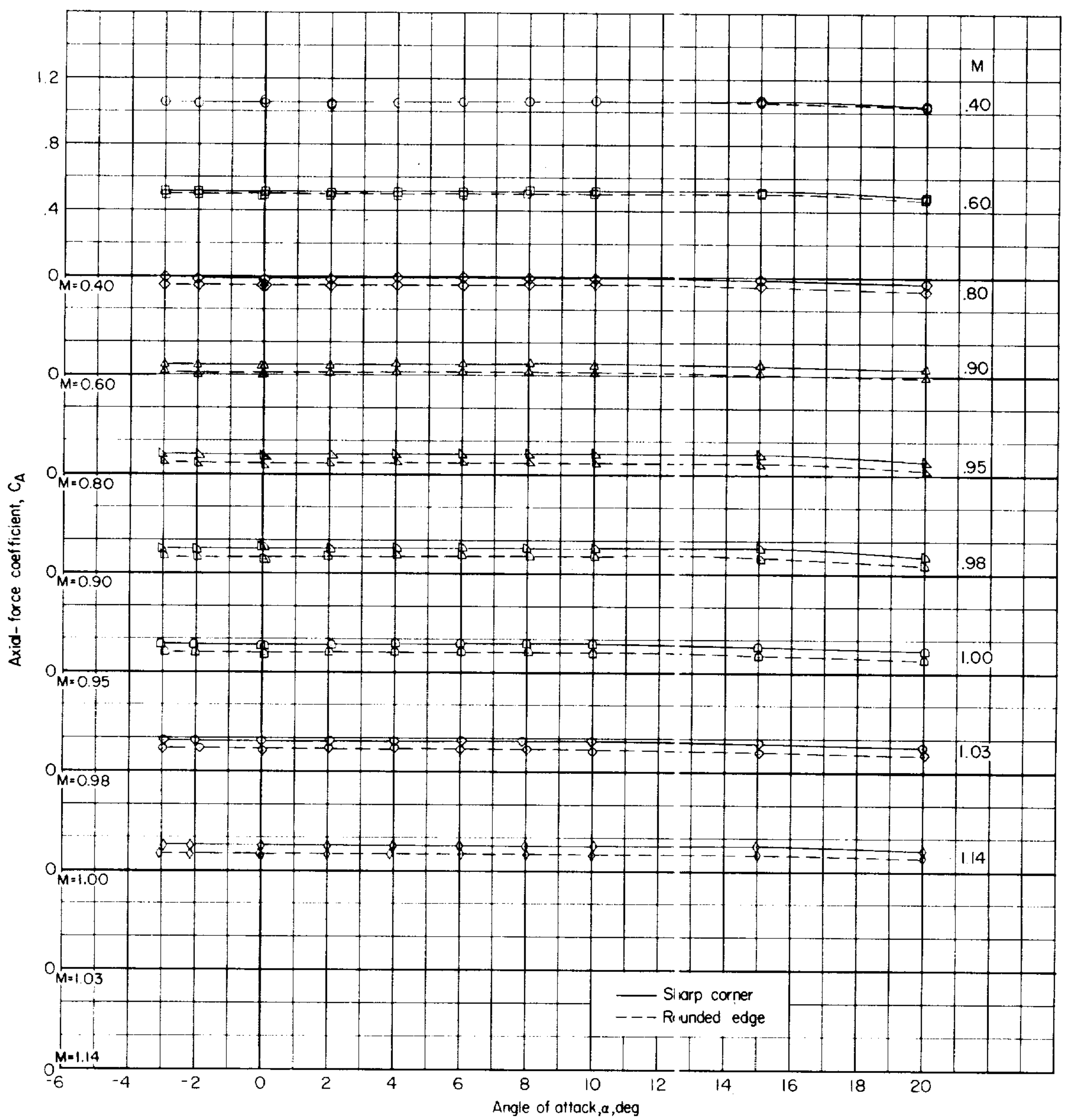
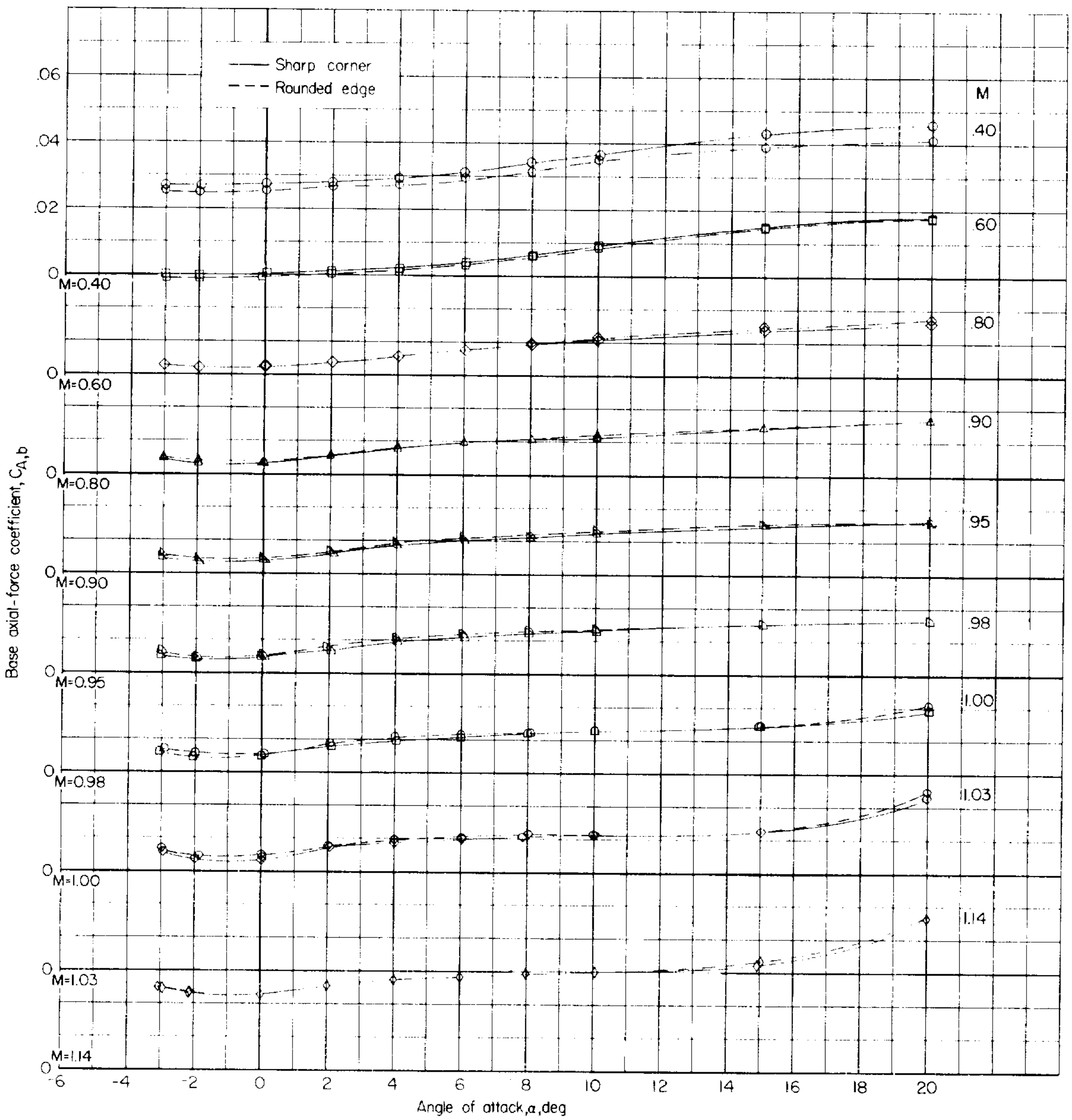


(c) Variation of C_A with α.

Figure 5.- Continued.



(d) Variation of $C_{A,b}$ with α.

Figure 5.- Concluded.

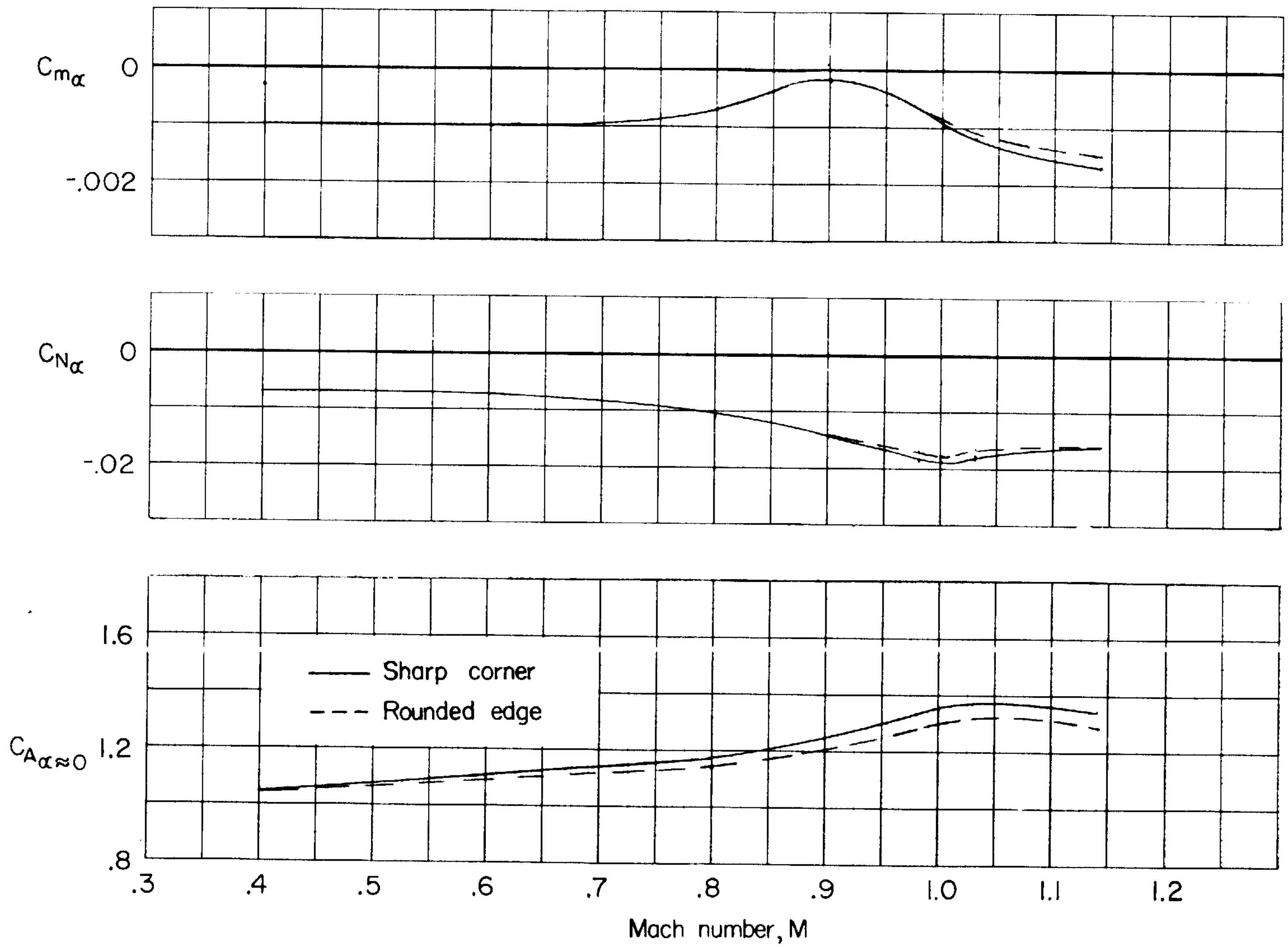


Figure 6.- Summary of static aerodynamic characteristics of model.